Translator's Declaration

I, the undersigned Tamás Bokor, of Budapest, Máriaremetei út 26, H-1028 Hungary, hereby declare that I am an experienced translator between the Hungarian and English languages, and that the attached text is a true translation of the Hungarian Patent Application No. P 02 03993, which translation has been prepared by me.

Budapest, 10/06/2003

Signed:

Date: 6th of October, 2003, Budapest

BOKOR, Tamás

Optical system for a binocular video spectacle

(László Domján, Gábor Szarvas, Szabolcs Mike)

Functional description

This invention concerns novel optical solutions for use in video spectacles (head-mounted displays (HMDs)), which fulfil the requirements of such HMDs, allowing the HMDs to display TV-pictures, for viewing DVD-films and for presenting 3D images of game consoles etc. in a good quality. The most important parameters of these devices are the following: image resolution, the distance of the virtual image, the size of the virtual image (or the angle of the virtual image), the distortions of the virtual image, the adjustment range of the exit pupil (inter pupillar distance=IPD), dioptre correction possibility, light loss - power consumption, weight, price, and further the possibility to display both monoscopic and stereo images images.

The resolution of the images is at least. 800x600 pixels. ~1.5m (52"-56") image diameter is acceptable as the size of the virtual image viewed from a distance of 2 meters, i. e. the angle of view is ~25°. The IPD may vary between 45 and 75mm for different head sizes. For the compensation of the human nearsightedness a ±3 dioptre correction possibility is sufficient. If only one microdisplay is used in the HMD, the price and the weight of the device can be reduced, which single microdisplay may be positioned in the middle relative to the head, and the image of this microdisplay is enlarged for both eyes. When displaying stereoscopic images, the images of different perspectives are directed to the left and the right exit pupil using a time-sharing principle. Using only one microdisplay beams coming from the display must be split towards the two exit pupils.

Based on the above, the functional units of the optical system of a 1-display HMD are the following:

- The display and the associated illumination
- The optical arrangement suitable for splitting the beams coming from the display
- The eye-optics, which produces the appropriately enlarged virtual image for the eyes

In this invention we present solution for these optical subsystems fulfilling the above requirements.

- Beam splitting

We can find several solutions for splitting of beams emanating from a single display, where the display is positioned in the centre. Most of these solutions are based on the angular separation of the beams, i. e. the beams being diffracted from each display pixel are separated according to the direction of the beams. The resolution of the enlarged image perceived by the human eye depends from the diffraction angle of the beams, so for this reason the angular separation causes loss of information and decreased resolution.

Such an example may be found in patent US 5392158 /Tosaki, Sega/, here the beams are split either by using the inner reflection of a prism-wedge positioned close to the display, or by a pair of full-reflection mirrors with an included angle of 90° ±45°, the mirrors being positioned symmetrically to the optical axis, with their touching edge turning towards the display (V-mirror).

A similar, so called V-mirror split may be found in US patent 5682173 /Holakovszky/ as well. In spite of a loss-free split, the different information content of the beams reflected in the different directions causes problems, and further the images perceived by the left and the right eyes have different inhomogeneity, and the optical transfer is also riddled with trapezoidal distortion. If the beam splitting element is too close to the display, some parts of the image may not even reach both eyes, and the effect of the prism-wedge or the touching edge of the pair of mirrors also decreases the image quality. Farther away from the display the split beams occupy larger space, hence larger optical elements must be used, which increases the physical size of the device and does not permit the use lenses with shorter focus.

In US Patent No. 5739955 /Marshall, Virtuality IP/ and in US patent No. 6246383 /Ophey, Philips/ beams are split with a pair of semi-transparent mirrors which cross each other vertically ("vertically offset beam splitter"), and with a reflective focusing element (concave mirror). The effect of the edges of the mirrors causes the same problem as above and the vertical resolution is also reduced. A collimated display illumination is used, and the crossed mirrors are put into the focal point, so a splitting volume is compact. A big disadvantage is that 75% of the light is lost because of the semi-transparent mirrors, only half of the light beams coming from the display go through the mirrors towards the focusing element, and after reflection therefrom, the half of these is further reflected towards the pupils. Because of the loss of light the design of the illumination system becomes complicated, and the power consumption of the device will be necessarily higher. A part of the lost light reaches the eyes and causes noise so the image quality will be reduced. The concave mirror increases the size of the system. Using reflective liquid crystal display the illumination unit must be placed between the splitting mirrors and the display, which will further increase the size of the system.

In patent No. WO 8504961 /Cook/ a system having proved suitable in other optical arrangements, the so called X-prism is used to divide light beams coming from the display, using the inner reflection of the prism. The big disadvantage of the X-prisms as compared to the mirrors is that it increases the weight of the application, because it is made of glass, and making it of plastic is difficult. The light scattered on the edge of the X-prism causes noise in the image. With a split using X-prism, even in the best case there is a 50% loss of light.

In patent No. WO 0159507 /Holakovszky/ a so called X-mirror is used for beam splitting close to the display, instead of an X-prism. Since no collimated display illumination and focusing elements are used before beam splitting, the size of the X-mirrors must be relatively large, and no eye-optics having a short focus on the object side may be used. Other disadvantages of this construction are the 50% loss of light. The design of the crossing mirrors and the minimization of the scattered light of in the crossing is a serious problem in the X-mirror construction. In the volume occupied by the large-sized X-mirror, no further optical imaging elements may be located (lenses, mirrors), and thereby the achievable image size and image quality further decreases.

From the above it is apparent that in most cases the size of the beam splitting elements is relatively large, because the splitting volume must contain all light beams coming from the display. Using a large splitting element makes its harder to design a small IPD optical system, because the magnifying optics forming the enlarged virtual images may not be positioned close to the display. There are two cases when the size of the splitting volume may be kept small, if it is close to an image plane or to a focal point. An essential element of the present invention is that we realize the splitting in a space (volume) near the image-side focal plane of

a lens system, using collimated display illumination and a small focal length lens system. In this manner it is possible to use a small-sized splitting-mirror system. In *Fig. 1*, *Fig. 2* and *Fig. 3* an optical arrangement may be seen which realizes the beam splitting in the focal spot (104, 204, 304) is with a pair of mirrors (103,203,303) arranged symmetrically to a plane which is perpendicular to the optical axis, the mirrors subtending with angles of 90° +-45° with each other, from which mirrors the mirror that is crossed by the light beams first has 50% transparency, while the other mirror is totally reflecting.

The first member of the above mirror pair may be a polarization beam splitter mirror (PBS-polarization beam splitter) as well, which is made by several companies, (for example the company Balzers). In *Fig.4.* such an arrangement can be seen, the first part of the pair of mirrors (405) is a PBS.

When displaying monoscopic images it should be made sure that the beams coming from the display towards the splitting mirror contain both polarization states to equal extent. This can be achieved using a polarization element. When displaying stereoscopic images a controllable liquid crystal polarization rotator 403 can be used for directing images for the left and the right eye to the left and right pupils alternately, according to a time sharing principle. Such polarization rotators are produced, for instance, by the companies Displaytech and CRL-Opto. A big advantage of this solution is that it provides theoretically loss-free beam splitting, contrasted with the patents explained before, where the two light paths can only be switched on and off after the beam splitting in alternating manner, by means of shutters, which results in 50% of the total amount of light being shuttered at any given moment; and where two shutters must be used.

Stereo images can be displayed without losses employing the solution where the first part of the splitting mirror 405 is a so called controllable shutter which behaves in one of its operating states as a 100%-reflective mirror, while in the other operating state it is fully transparent.

Using collimated display illumination has several advantageous aspects, e.g. the splitting volume is reduced and the numerical aperture of the optical system is also reduced so the optical design becomes much easier and the optical system is made simpler.

The focal spot is generated by means of a lens or a lens system 102, 202, 302. Using focusing lenses - instead of the focusing mirrors described in US patents Nos. 5739955 and 6246383 - is advantageous for a number of reasons. It provides for loss-free beam splitting of the light coming from the display; ensures a smaller splitting volume; and by using a reflective display the focusing lenses can perform a dual function: on the one hand they can accomplish the collimated illumination (discussed later in this document) and on the other hand they focus the light reflected from the display into a small volume, so the optical system becomes simpler and its size is further reduced.

It is important that if the beam splitting is not symmetrical with respect to the optical axis then later the compensation of the difference of optical path lengths have to be provided for.

Alternatively, as it is disclosed in US patents Nos. 5392158 and 5682173, splitting in the focal spot of a lens can also be carried out with a pair of mirrors arranged at a given angle and disposed symmetrically with respect to the optical axis (*Fig.5.* 504). In this case the inhomogeneity difference of the images seen by left and right eyes can be eliminated because

of the focal spot splitting. The horizontal resolution obviously decreases in this case because of the angular division of the beams.

- Display illumination

The focusing lens used for producing the focal spot can also be used for collimated illumination of the display, if the light source 601 is put into the image-side focal point and the display is illuminated through a polarization splitting mirror 604 (see *Fig.6.*). In the present solution the display is reflective. Because of the polarization splitting mirrors, the light going through the splitting mirrors and arriving at the display is polarized. In case a liquid crystal display is used, the bright pixels thereof rotate the polarization so the light coming from the direction of the display to the polarization splitting mirror is reflected towards the splitting element 605 theoretically without any loss. If the display is not of the liquid crystal type (i. e. it does not modulate the polarization of light, e.g. a micromirror block), then a 50% -reflection mirror can be used.

If 2 light sources are used in the illumination arrangement shown in *Fig. 6* (see *Fig. 7*, 701,702), with the light sources located in the focal plane of the lens 704, then it becomes possible that after reflection from the display and passing through the lens again 2 focal spots are produced in the splitting volume, corresponding to the two light sources. This method can be used advantageously for the projection of stereoscopic images, if a pair of fully reflective mirrors arranged symmetrically with respect to the optical axis at a given relative angle, are utilised as splitting elements, which direct the beams from one focal spot toward one of the pupils and beams from the other focal spot toward the other pupil. When displaying stereoscopic images the two light sources are switched on and off alternately, according to the image refreshment frequency of the display. When displaying monoscopic images, both light sources are switched on at the same time. If the light sources are moved in the focal plane, the location of the focal spots may be also changed, which can be utilized for achieving IPD correction.

The light source can be a combination of R, G, B (red, green, blue) LEDs or a white light source as well. Using LEDs the light source has to be designed such that the three LEDs illuminate the display from a single virtual point. A solution can be seen in *Fig. 8*, where two color-selective mirrors are applied. The red light coming from the R-LED 801 can pass the first filter mirror 804 towards the display, but the green light coming from the G-LED 802 is reflected from the filter towards the display. Red and green light can pass through the second filter mirror 805, but the blue light coming from the B-LED 803 is reflected from said filter mirror towards the display. The specification of the color-selective mirrors is determined by the wavelength of the used LEDs. A possible LED combination from the LEDs of the Nichia is company is: blue – 470nm, green – 530nm, red – 630nm. In this form the illumination unit is theoretically free from loss.

- Eye-optics

Collimated display illumination has been used in order to produce a small focal spot, but because of the collimated display illumination, the relatively small angular range of the beams coming from individual pixels has to be increased to an suitable level. That can be achieved by means of a diffraction element, more particularly a diffusor disposed in the image plane. In the eye-optics shown in Figs. 1 and 2 reflective diffusors 207, 208 are applied, whereas the solution shown in Fig. 3 comprises transmissive diffusors 309, 310. The use of diffusors is

wide-spread in other imaging devices (projectors, monitors, etc.). Reflective and transmissive diffusors are produced for instance by the company POC. In US patent No. 6094309 /Ophey, Philips/ diffractive optical elements are applied as a part of a HMD eye-optics, but in said patent these elements are used only for enhancing the image quality, for correcting distortions and not for increasing the angle of view.

An important design consideration for eye-optics solutions is that the minimal number of elements (lenses, mirrors) should be used, with the envelope size of the device being usually given. Consequently, the size of the exit pupil cannot be sufficiently increased to provide for the whole IPD setting range, the mechanical displacement of system elements is also necessary.

In the optical arrangement shown in *Fig. 1* after the beam splitting the image of the display is produced by means of the first members of the eye-optics 105, 106 on a reflective diffuse surface (107, 108), this surface can either be flat or concave. The light beams are directed towards the reflective surfaces 107, 108 by semi-transparent mirrors (50% or polarization mirrors) 109, 110, through which the light reflected from the reflective surfaces passes again (folded optical path) and goes through the last part of the eye-optics 105, 106 towards the exit pupil. In this arrangement IPD can be set by moving the right and left side blocks 113, 114 of optical elements shown in the figure. By moving the reflective surfaces 107, 108 the focus and the dioptre correction can be adjusted. Examples of a folded optical path can be found in PCT patent No. US 5838490 /Fritz, Honeywell/, but there for magnification in the eye-optics lenses and directly behind them curved reflective surfaces („mangin mirrors") are used.

The operating principle of the arrangement shown in *Fig. 2* is very similar to that of the solution shown in Fig. 1, with the difference being that in the arrangement of Fig. 2 IPD is adjusted not by moving the diffusors, but by moving the semi-transparent mirrors 209, 210 together with blocks 213, 214. Focus setting is provided by moving the last members of the eye-optics 205, 206.

The beam splitting arrangement of *Fig. 3* is similar to what has been described above, with the first members of the eye-optics 305,306 producing the image of the display in an image plane 309, 310 where a transmissive diffusor is disposed. Light beams are directed towards the diffusors by flat mirrors 307, 308. From the diffusors light beams go through the last members of the eye-optics 305, 306 to the exit pupil. The correct IPD and focus can be set by moving the mirrors 307, 308 and the left and right optical blocks in the direction of the arrows shown in the figure.

A simple solution for IPD setting can be seen in *Fig. 5,* where a large focal spot 503 is applied, with non-collimated display illumination and a pair of full-reflection mirrors, arranged at a given relative angle and disposed symmetrically with respect to the optical axis, is moved within the focal range. In this manner different regions of the focal plane, and thereby light beams leaving the display and having different angles can be projected towards the eyes. A similar solution is achieved, when in the arrangement shown in *Fig. 7,* the light source (one or more) is moved in the direction of the arrows, while the splitting mirrors are not moved.

Apart from the examples shown in Figs. 1, 2, 3, and 5, requirements for HMDs can be fulfilled by other eye-optical solutions as well by changing the location of different elements, but it is crucial that IPD setting and focus adjustment should be made in different steps.

Claims

1. Optical sytem of a binocular/biocular head mounted display comprising a small size display ("microdisplay") disposed between the eyes symmetrically or slightly asymmetrically relative to the two eyes, wherein the light originating from the display is focused by a focusing (positive) lens or lens system into an area surrounding the back focal point of said lens or lens system, and wherein the light beam is split into two for the two eyes by means of a small-size splitting element disposed in or near said back focal point. From the split beam two real images are produced in identical relative positions with respect to the two eyes by means of a suitably arranged optical system, with magnified virtual images of the display being produced before each of the eyes from said real images by two eye lenses located before the eyes.
2. The apparatus according to Claim 1 in which the splitting element performing the beam splitting for the two eyes comprises a semi-transparent mirror surface making advantageously an angle of +45deg with the optical axis of the focusing lens and a fully reflecting mirror surface making advantageously an angle of –45deg with said axis. The semi-transparent surface intersects the optical axis of the focusing lens closer to the lens than the fully reflecting one.
3. The apparatus according to Claim 2 wherein the semi-transparent mirror surface is a polarisation beam splitter.
4. The apparatus according to Claims 2 and 3 in which the semi-transparent and 100% reflecting surfaces are formed on two surfaces of a microprism.
5. The apparatus according to Claim 1 in which the splitting element performing the beam splitting for the two eyes comprises a 100% reflecting mirror surface making an angle of advantageously +45deg with the optical axis of the focusing lens system, and a 100% reflecting mirror surface making an angle of advantageously -45deg with said axis. The two reflecting surfaces intersect the optical axis of the focusing lens advantageously at the same point.
6. The apparatus according to Claim 5 in which the planar fully reflecting surfaces are formed on two surfaces of a microprism.
7. The apparatus according to Claim 1 in which the splitting element dividing the beams for the two eyes is a small size X-prism or X-mirror comprising advantageously 50% - reflective surfaces.
8. The apparatus according to any of Claims 1, 2, 3, 4, 5, 6, and 7 wherein the microdisplay is illuminated with a collimated beam of small divergence angle.
9. The apparatus according to Claim 8 comprising a reflective microdisplay, where the small divergence angle beam illuminating the display is produced by the focusing lens. Between the focusing lens and the microdisplay either a polarisation beam splitter or a semi-transparent mirror is placed such that it makes an angle of advantageously 45deg with the optical axis. A small size light source is placed in the focal point of the focusing lens that is mirrored by the semi-transparent mirror or the polarisation beam splitter. The small size beam splitting element is placed in the proximity of the non mirrored focal point of the focusing lens.
10. The apparatus according to any one of Claims 1, 2, 3, 4, 5, 6, and 7 wherein the real images of the microdisplay are produced before the eyes on transmissive or reflective diffusing surfaces to enlarge the viewing angle of the virtual image.
11. The apparatus according to Claim 10 in which, following the splitting element, the optical axes of the elements producing the images for the left and right eyes run advantageously parallel with the line connecting the two eyes, towards the eye mirrors located before each eye; and after the reflection from said eye mirrors the beam paths

are directed towards the eyes. The real images of the microdisplay are produced on transmissive diffusors disposed between the eye lenses and the eye mirrors, with said transmissive diffusors being perpendicular to the optical axes. An eye lens system is located between the eyes and the transmissive diffusors, projecting magnified virtual images of the desired size of the real images into the eyes.

12. The apparatus according to Claim 11 wherein the IPD correction is achieved with the following synchronised movements:
    - the eye mirrors are moved in a direction parallel with the line connecting the eyes
    - the left eye lens system and diffusor are moved together as a block in the plane defined by the axes of the left and right eye lens systems in the direction of a line subtending an angle of 45deg with the axis of the left eye lens system
    - the right eye lens system and diffusor are moved together as a block in the plane defined by the axes of the left and right eye lens systems along the direction of a line subtending an angle of -45deg with the axis of the right eye lens system.
13. The apparatus according to Claim 11 in which the IPD correction is achieved by the following synchronised movements:
    - the left and right eye lenses and diffusors are moved as two blocks in opposite directions along a line parallel with the line connecting the two eyes
    - the entire optical system except the left and right eye lens systems, diffusors and eye mirrors is moved in a direction parallel with the optical axes of the eye lens systems
14. The apparatus according to Claim 11 in which the IPD correction is achieved by the following synchronised movements:
    - the left and right eye lens systems are moved as two blocks in opposite directions parallel to the line connecting the two eyes
    - the entire optical system excluding the left and right eye lens systems, diffusors and eye mirrors is moved in a direction parallel with the optical axes of the eye lens systems.

    In this embodiment stationary diffusors of larger lateral size are used.
15. The apparatus according to Claim 11 wherein the IPD correction is achieved by the following synchronised movements:
    - The mirror surface of the splitting element reflecting light towards the left eye and all the optical elements through which light is transmitted into the left eye are rotated as a rigid optical block around an axis perpendicular to the plane of the display.
    - The mirror surface of the splitting element reflecting light towards the right eye and all the optical elements through which light is transmitted into the right eye are rotated as a rigid block around an axis parallel with the axes of the eye lens systems in a direction opposite to the direction of rotation of the left block.
16. The apparatus according to any one of claims 11, 12, 13, 14, and 15 wherein the correction of near- or farsightedness (dioptre correction) is achieved by moving the left and right eye lens systems relative to the diffusors, in a direction parallel with the optical axes of the lens systems. Additionally, for supporting the dioptre correction a pattern (e.g. hair-cross) is disposed on the part of the diffusors that falls outside the real image of the microdisplay.
17. The apparatus according to Claim 10, comprising a reflective diffusor corresponding to each eye, with real images of the microdisplay being produced on said reflective diffusors; and further comprising a semi-transparent mirror and an eye lens system for

each of the eyes. The reflective diffusors are located in planes perpendicular to the line connecting the two eyes and outside the spatial area including the eyes, more particularly to the left from the left eye and to the right from the right eye. The semi-transparent splitting mirrors are disposed directly in front of the eyes, making angles of +45 deg and –45 deg with the line connecting the two eyes so that said mirrors direct the light coming from the reflective diffusors towards the eyes. The eye lens systems are located advantageously between the eyes and the semi-transparent mirrors, with the function of the eye lens systems being to produce magnified virtual images from real images created on the diffusor and project them into the eyes.

18. The apparatus according to claim 17 wherein the reflective diffusors are spherical or aspheric curved surfaces.
19. The apparatus according to any of claims 17 and 18 wherein the IPD correction and the correction of near- or farsightedness (dioptre correction) is achieved by the synchronised movement of the following elements:
   - by moving the semi-transparent splitting mirrors parallel with a line connecting the eyes
   - by moving the eye lens systems parallel with the optical axes of the eyes
20. The apparatus according to any of claims 17 and 18 wherein the IPD correction is achieved by the following synchronised movements:
   - The mirror surface of the splitting element reflecting light towards the left eye and all the optical elements through which light is transmitted into the left eye are rotated as a rigid optical block around an axis perpendicular to the plane of the display.
   - The mirror surface of the splitting element reflecting light towards the right eye and all the optical elements through which light is transmitted into the right eye are rotated as a rigid block around an axis parallel with the axes of the eye lens systems in a direction opposite to the direction of the previous rotation.
21. The apparatus according to any of claims 1-20 wherein the low divergence-angle collimated illumination is provided by the application of red, green, blue LED chips, a special color filter transmitting red and reflecting green light, and another special color filter transmitting red and green but reflecting blue light. The above optical elements are disposed such that the red, green and blue LED chips are mirrored into the same virtual point. An advantageous arrangement realising this concept is the following:

- the special color filters are placed parallel with each other
- the red LED is positioned such that the optical axis thereof makes an angle of 45 deg with the color filter plates and the light emitted by the LED propagates through both color filters
- the green LED is positioned such that the optical axis thereof makes an angle of -45 deg with the color filter plates and the green light emitted by the LED is reflected from the color filter transmitting red and reflecting green light and the light subsequently passes through the other color filter. The reflecting color filter plate creates the virtual image of the green LED in the geometrical position of the red LED.
- the blue LED is positioned such that the optical axis thereof makes an angle of -45 deg with the color filter plates and the light emitted by the blue LED is reflected from the color filter transmitting red, green and reflecting blue light but the light is not let through the other color filter. The reflecting plate creates a virtual image of the blue LED in the geometrical position of the red LED.

22. Optical sytem of a binocular/biocular head mounted display comprising a small size display ("microdisplay") disposed between the eyes symmetrically relative to the two eyes, wherein the light beams originating from the display are passed into a focusing (positive) lens or lens system, with a larger-size movable V-mirror being disposed at the proximity of the back focal plane of the lens or lens system for splitting the light beams for the two eyes, with the angle between the two surfaces of said V-mirror being 90 deg. By moving the V-mirror along a line parallel with the axis of the focusing lens different parts of the back focal plane are reflected towards the eyes in order to achieve IPD correction.
23. Optical sytem of a binocular/biocular head mounted display comprising a small size display ("microdisplay") disposed between the eyes symmetrically relative to the two eyes, wherein the light beams originating from the display are passed into a focusing (positive) lens or lens system, with a large-size V-mirror being disposed at the proximity of the back focal plane of the lens or lens system for splitting the light beams for the two eyes, with the angle between the two surfaces of said V-mirror being 90 deg. The apparatus further comprises two independently controllable and movable light sources that illuminate the display with two collimated beams of adjustable incidence angle, with the incidence angle being changed by moving the light sources; with the two collimated light beams originating from different light sources passing through the microdisplay or getting reflected by it, subsequently passing through the focusing lens, and in the back focal plane hitting opposite surfaces of the V-mirror; with one of the beams being projected in the right eye and the other beam projected into the left eye. IPD correction can be achieved by moving the light sources. By controlling the two light sources according to a time sharing principle 3D stereoscopic images can be displayed.
24. The apparatus according to claim 3, wherein the liquid crystal display is illuminated with polarized light, and an electronically controllable electro-optical element is disposed in the optical path between the display and the beam splitting element, where said electro-optical element is applied for rotating the direction of polarization of light. By rotating the polarization of light with 90 deg the light can be controllably reflected to the left or right eye from the beam splitting element, enabling the displaying of 3D stereoscopic images.
25. The apparatus according to any one of claims 1-21 wherein a pair of light shutters, one for each eye, is placed in the optical paths between the beam splitting element and the eyes. With a time-shared control of the two light shutters, 3D displaying is possible.

FIG.1.

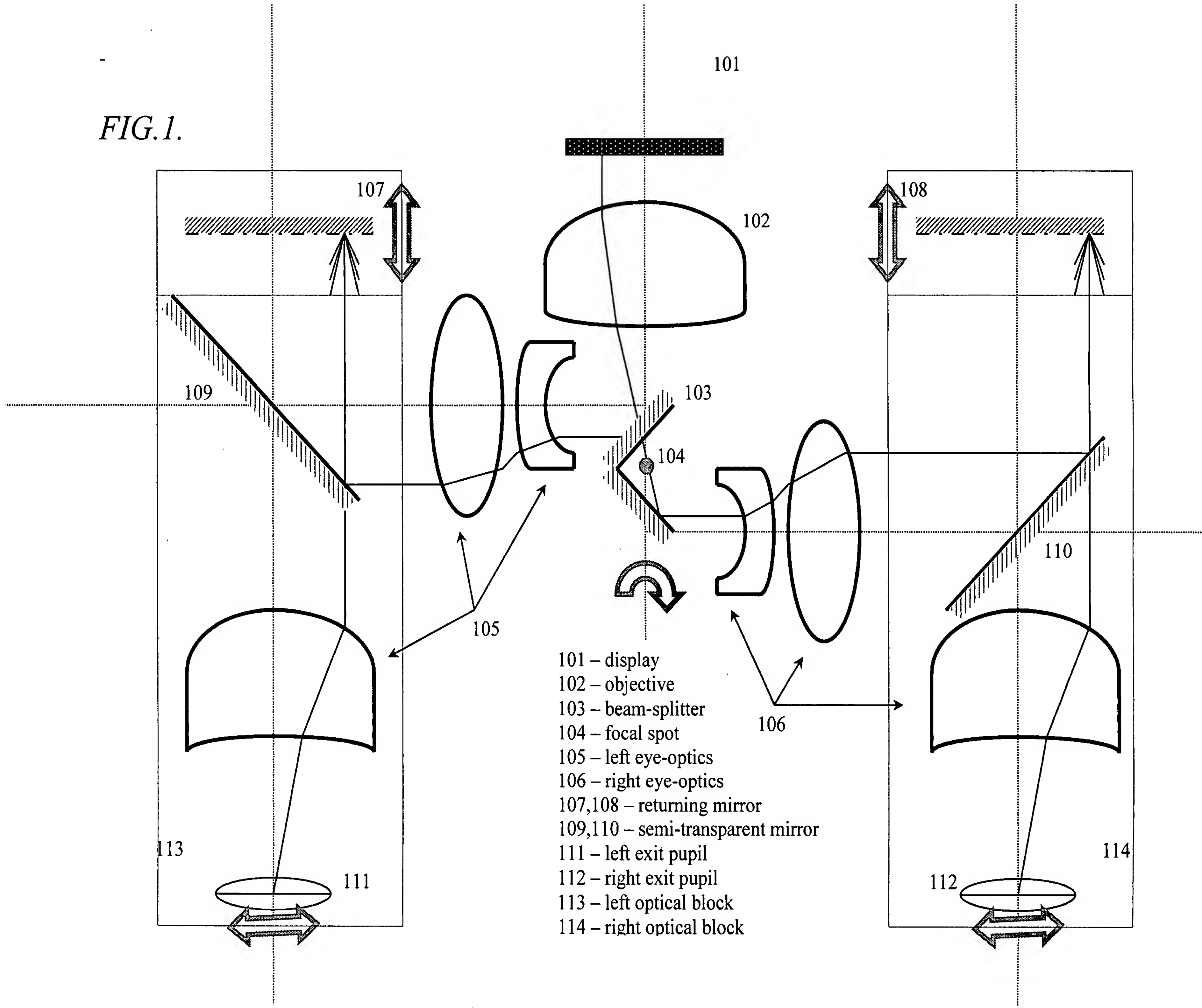
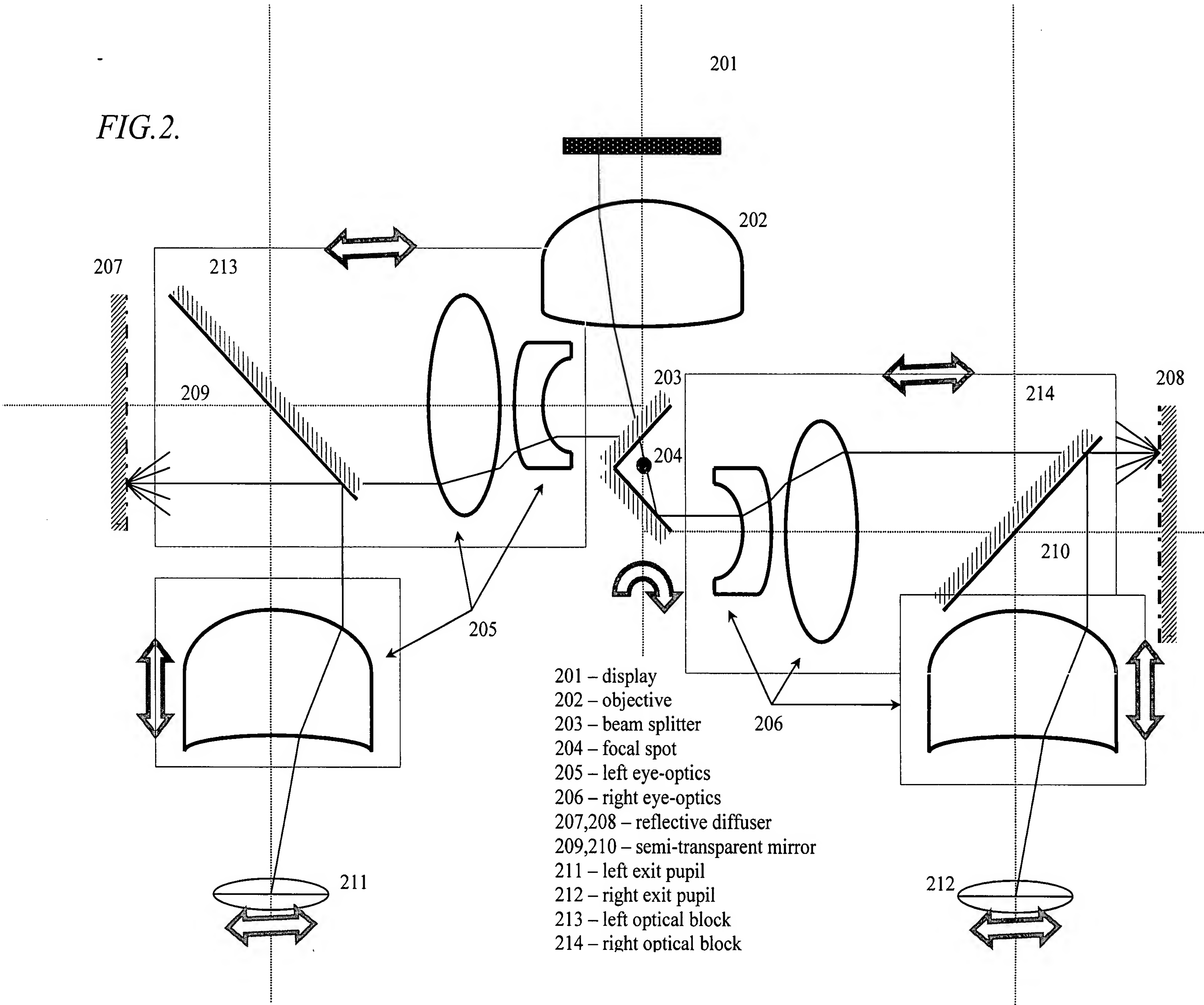
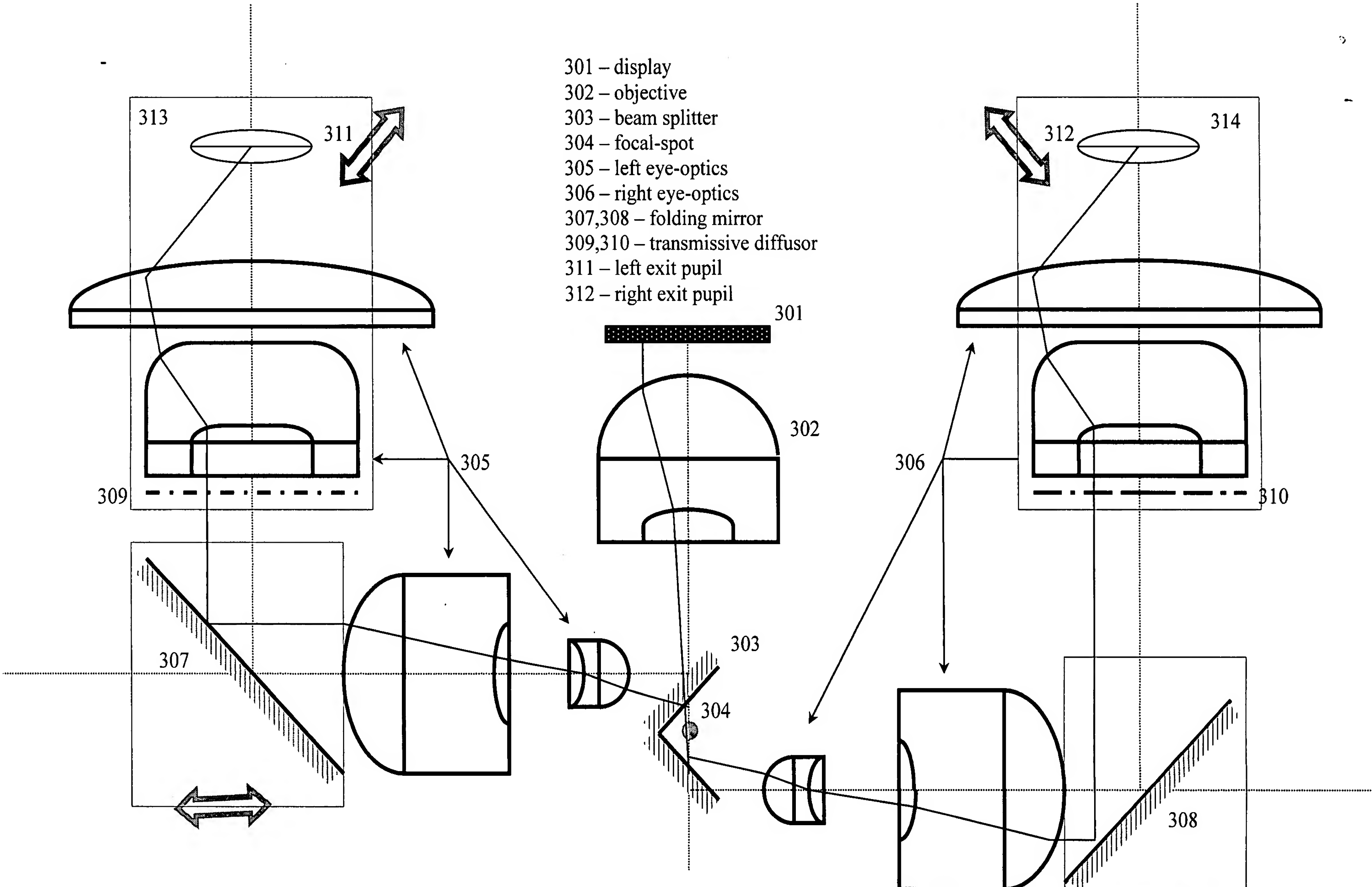

101
102
103
104
105
106
107
108
109
110
111
112
113
114
101 – display
102 – objective
103 – beam-splitter
104 – focal spot
105 – left eye-optics
106 – right eye-optics
107,108 – returning mirror
109,110 – semi-transparent mirror
111 – left exit pupil
112 – right exit pupil
113 – left optical block
114 – right optical block

FIG.2.

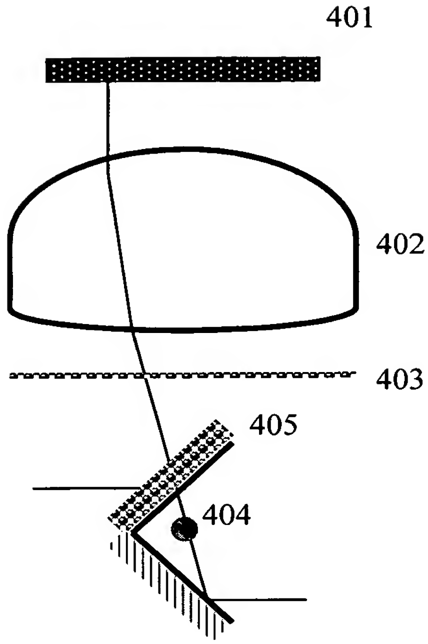

201
202
203
204
205
206
207
208
209
210
211
212
213
214
201 – display
202 – objective
203 – beam splitter
204 – focal spot
205 – left eye-optics
206 – right eye-optics
207,208 – reflective diffuser
209,210 – semi-transparent mirror
211 – left exit pupil
212 – right exit pupil
213 – left optical block
214 – right optical block



313 – left optical block
314 – right optical block
325 - optical axis

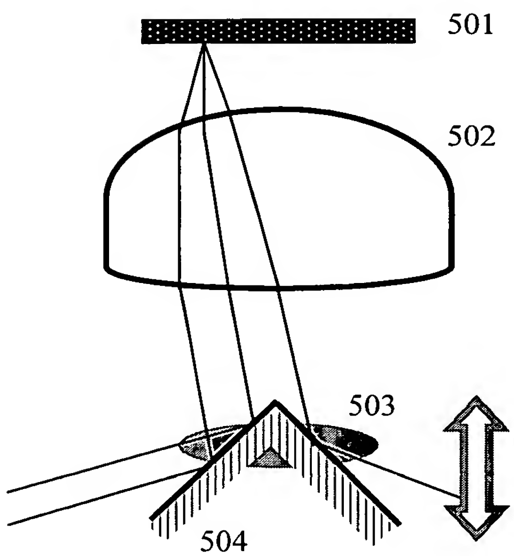
FIG.3.

FIG. 4.



401 – display
402 – objective
403 – polarization rotator
404 – focal spot
405 – beam splitter

FIG. 5.



501 – display
502 – objective
503 – focal spot
504 – beam splitter

FIG.6.

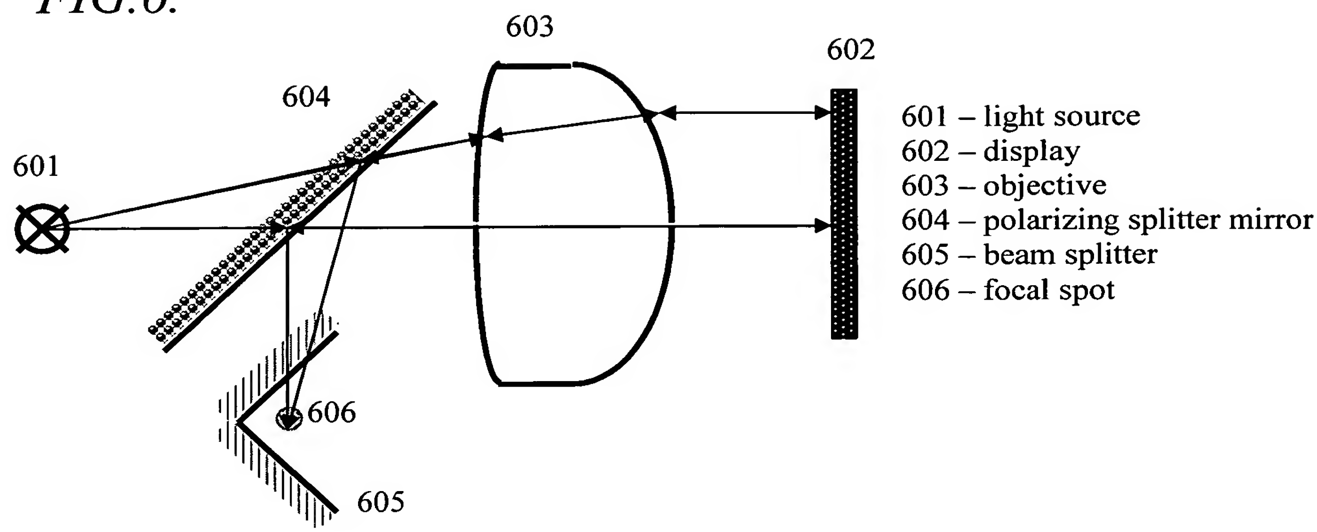

603
602
604
601
606
605
601 – light source
602 – display
603 – objective
604 – polarizing splitter mirror
605 – beam splitter
606 – focal spot

FIG.7.

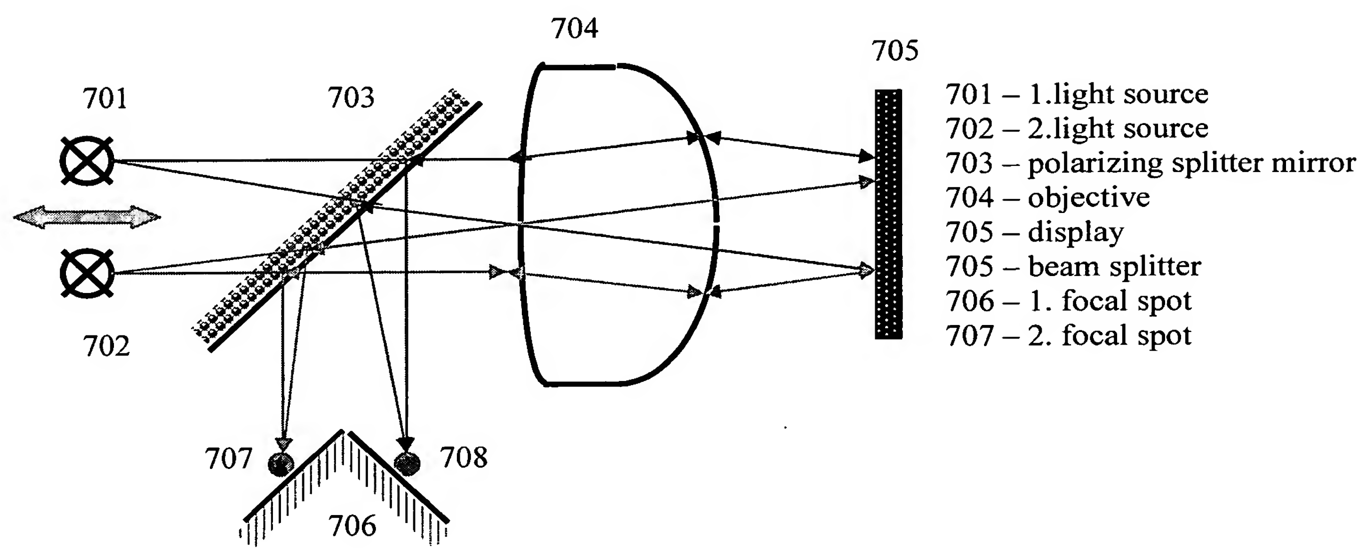
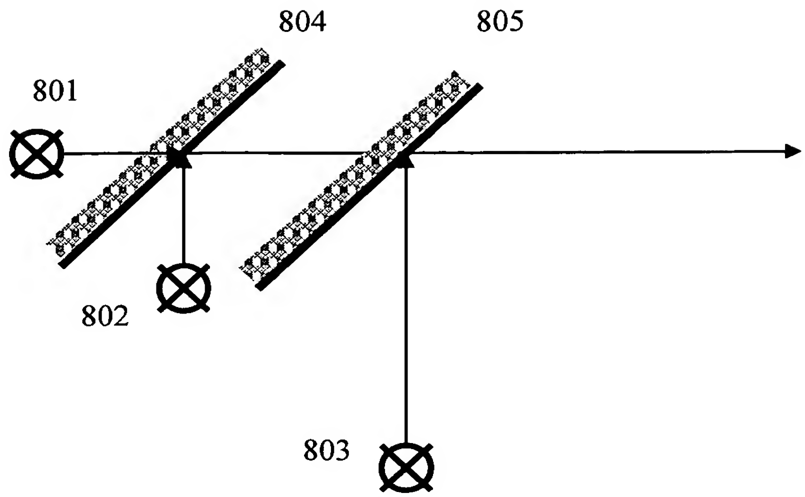

704
705
701
703
702
707
708
706
701 – 1.light source
702 – 2.light source
703 – polarizing splitter mirror
704 – objective
705 – display
705 – beam splitter
706 – 1. focal spot
707 – 2. focal spot

FIG.8.



801 – Red LED
802 – Green LED
803 – Blue LED
804 – Color filter mirror
805 – Color filter mirror